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The equity impacts of bus rapid transit

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THE EQUITY IMPACTS OF BUS RAPID TRANSIT: A REVIEW OF THE EVIDENCE, AND IMPLICATIONS FOR SUSTAINABLE TRANSPORT

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ABSTRACT

The paper offers an analysis of empirical evidence on the equity impacts of operational Bus Rapid Transit (BRT) systems in the Global South. The focus is on vertical equity, i.e. whether BRT systems achieve progressive benefits for poorer segments of the population. Findings from Africa, Asia and Latin America all suggest that BRT does offer significant benefits to low-income groups, in terms of travel time and cost savings, access enhancement, and safety and health benefits. However benefits are often skewed towards medium-income users and thus less progressive than they might be. Two primary reasons for this are insufficient spatial coverage, and inappropriate fare policies. While many features of BRT potentially allow it to deliver pro-poor outcomes, such outcomes only materialise if BRT implementers pay specific and sustained attention to equity. The paper identifies key issues that need to be addressed to steer BRT implementation towards more socially sustainable outcomes, critical amongst which is to improve integration with other transit, paratransit, and non-motorised transport services, and with the housing sector.

Keywords: Bus Rapid Transit, equity, poverty, social impact assessment, social exclusion, transport disadvantage

1. INTRODUCTION

This paper is broadly concerned with the question of how urban transport infrastructure projects, and Bus Rapid Transit (BRT) in particular, are able to contribute to social justice and social sustainability in cities of the Global South. Since the Brundtland report (Brundtland et

al., 1987) was published, sustainability or 'sustainable development' has been defined as a system whereby any unit (project, city, region, building, organization, or country) is able to exist without depleting the resources required by future units to themselves exist. More precisely, units should be economically sustainable, have minimum environmental impact, and be socially just.

With regard to the transportation system, the first two aspects of sustainability have been fairly widely discussed and measured; it is only recently that attention has turned more toward the social impacts of the transport system, and the concepts of transport equity and social justice (Lucas and Jones, 2012). The work of Eduardo Vasconcellos (2001) on urban transport and equity auditing in developing countries, Karen Lucas (Lucas, 2006; Lucas et al., 2008) on transport disadvantage and social inclusion, and Karel Martens and Aaron Golub (Golub and Martens, 2014; Martens and Golub, 2012) on using principles of justice to assess transport measures, have been particularly influential in enabling transport equity to gain traction in the policy discourse. Nevertheless, the concept remains fairly broad; key words needed when conducting a literature search include, for example, social equity, social justice, transportation poverty, social impacts, accessibility, transportation disadvantage, sustainable livelihoods, poverty alleviation, and social exclusion or inclusion.

Our concern is with BRT systems as one way of promoting socially sustainable mobility. BRT systems are widely acknowledged as being capable of improving urban mobility through a package of interventions, including busway improvements, efficient operations, and the upgrading of the urban environment (Cervero, 2013; Wright and Hook, 2007). BRT has also become an important strategy in the climate change arsenal: the International Energy Agency is promoting BRT deployment – to the extent of 25,000 km of new BRT lines worldwide – in an attempt to meet the mobility needs of cities while supporting global emission reduction targets (IEA, 2013). A recent count indicated that BRT-type systems were operational in about 206 cities around the world, the majority of which were built in the last 15 years (brtdata.org, 2017). A significant number of these are in the Global South.

The global literature on BRT is accordingly growing fast. A recent search retrieved more than 1,100 articles on BRT published in the academic and grey literatures in the past decade. A few review papers have appeared, focusing mainly on the design, operational, and ridership aspects of BRT (Deng and Nelson, 2011; Hensher and Golob, 2008; Hidalgo and Graftieaux, 2008; Wirasinghe et al., 2013). Several more introspective studies have appeared asking questions around the effectiveness of BRT systems in cities like Bogotá (Gilbert, 2008), Istanbul (Babalik-Sutcliffe and Cengiz, 2015), Bangkok (Wu and Pojani, 2016), and Ahmedabad (Mahadevia, Joshi, and Datey, 2012).

Issues of user impacts, and especially differential impacts across user groups, are underrepresented in this literature. This represents, in our view, an important research gap, as BRT systems are often implemented in cities characterised by high levels of inequality, informality, and low spatial quality (Jaramillo, Lizárraga, and Grindlay, 2012). Furthermore, BRT projects in developing countries are often rhetorically positioned as being pro-poor, and their political acceptability is often linked to a larger policy agenda aimed at alleviating poverty by improving access and reducing the costs of transport (Jennings, 2015; Lucas and Jones, 2012). Among the strongest proponents of this pro-poor approach is Bogotá mayor Enrique Peñalosa, who noted that Bogotá's TransMilenio was "[t]he single project that we implemented that most contributed to improve quality of life and gave citizens confidence in a better future" (CLAS, 2002). Lenders such as the World Bank and Interamerican Development Bank (IADB) also use equity as a motivation for financing BRT in many developing cities (Gilbert, 2008). It is thus appropriate to ask whether social goals are actually being achieved, firstly to further our understanding of how specific BRT design or operational elements affect different user and non-user groups, and secondly to examine how transport more broadly could play a more effective role in the global quest for poverty reduction and sustainable development.

While this is not a comparative study – we do not aim to compare the equity performance of BRT with that of other mass transit alternatives – it is useful to dwell briefly on one mode that typically dominates the environment within which BRT is implemented in the Global South,

namely paratransit. Paratransit or informal modes are characterised by unscheduled and informal operations, atomised ownership, and the use of smaller vehicles (ranging from motorcycles to mini- and midibuses). Paratransit services often deliver large benefits to poor populations, by providing service coverage in areas lacking formal transit, jobs for unskilled workers, and a high degree of customer responsiveness (Cervero and Golub, 2007). However these services also impose large costs related to increased traffic congestion, air pollution, and accidents due to poor driver behaviour.

Many governments have sought to address these problems by either reforming or banning informal operators. In paratransit reform BRT has come to play a large role, in a variety of ways. One approach is to comprehensively replace informal services with BRT, usually in concert with efforts to formalise and incorporate incumbent operators into BRT operating companies. Bogotá is an exemplar of this approach, aiming to incorporate approximately 21,000 buses, minibuses and microbuses belonging to 68 different associations (in 2000) into 21 concession contracts to operate trunk and feeder BRT routes and other parts of the city-wide integrated network (Hidalgo, Munoz, and Velásquez, 2016). At the other extreme, some cities such as Lima have not replaced paratransit but allowed it to operate in parallel to the BRT, thereby splitting the demand and exacerbating financial distress among paratransit operators. Recognising that there is little prospect of replacing paratransit, some African cities are seeking more constructive models of complementary and hybrid operations (Schalekamp and McLachlan, 2016). As the paper will show, the approach, pace, and comprehensiveness with which authorities deal with incumbent operators can have major equity consequences for both low-income passengers and operators.

The paper is divided into the following sections: first, we sketch the background in terms of the emerging scholarly interest in transport equity, including both definitional and measurement issues. The next section provides an overview of empirical findings on the equity impacts of BRT in the Global South, drawing exclusively on *ex post* studies reflecting the actual user impacts of implemented systems. The evidence includes direct user benefits such

as travel time and cost; wider impacts on accessibility, property, health, and employment; the use of ridership characteristics as a proxy for distributional impacts; and the project-level distribution of benefits and costs across income groups. The concluding section reflects on key requirements for improving the social effectiveness of BRT, and offers recommendations for further research, both of a methodological and a substantive nature.

2. DEFINING AND MEASURING TRANSPORT EQUITY

2.1 Conceptual issues

Equity or justice is usually described in terms of the fairness with which the impacts of an intervention are distributed: in this case, essentially, a more fair, equitable distribution of the benefits and disadvantages of transportation interventions (Golub and Martens, 2014; Litman, 2016).

Equity can be defined in different ways. Horizontal equity reflects an egalitarian understanding of the concept, and demands that no single individual or social group should be favoured more than others. Vertical equity, on the other hand, is concerned with the distribution of impacts between individuals and groups who differ in abilities and needs, for example by income or social class, or in transportation ability and need.

Vertical equity is of particular interest in situations where the inequitable distribution of transportation benefits and impacts contributes to an inability among some social groups to access the opportunities (education and economic opportunities, for example), goods, services and social involvement necessary to live one's daily life (Jennings, 2015; Lucas and Jones, 2012; Martens, Golub and Robinson, 2012). Much of the international literature considers ways in which to identify the transport-disadvantaged (e.g. Priya and Uteng, 2007; Shaw, 2005; Stanley and Vella-Brodrick, 2009). Once identified, vertical equity principles

would direct greater opportunities and resources to such individuals or groups, in alignment with the promotion of social or environmental justice and social inclusion. Thus a disadvantaged individual or group would receive more net benefits than others in a progressive system, and less in a regressive system.

Issues of vertical equity are particularly salient in the Global South, where large disparities exist in the distribution of transportation costs and benefits across social groups (Bocarejo and Oviedo, 2012; Howe and Bryceson, 2000; Lucas, 2011). These disparities usually have both income and spatial components: in the context of poorly developed public transport networks and constrained housing delivery systems, a lack of car ownership often severely constrains the mobility and accessibility available to an individual, a situation exacerbated by the poor location of low-income households relative to urban and transport opportunities.

2.2 Methodological approaches to measuring transport equity

In parallel to the conceptual development of transport equity there has been a growing interest in the empirical measurement of the distributional impacts of transport across groups. However, measuring transport equity and its impacts can be challenging because of the range of definitions adopted: without a clear understanding of what, precisely, is to be fairly distributed, how it is to be measured, and how groups are to be defined, equity impacts have tended to be evaluated inconsistently, or not at all (Litman, 2016).

For the purpose of this paper we classify approaches to measuring equity impacts according to the group experiencing the impact, and the method of allocation (see Table 1). *Direct impacts* include travel time and cost changes, road safety impacts, and health impacts experienced by users of the transport system of interest. Distributional impacts are usually measured by directly comparing impacts for different user groups (termed here *direct allocation*), such as accident rates estimated for different income groups. In some cases, the

direct impacts are not measured separately but the income distribution of the user population is used as a proxy for the distribution of the entire bundle of user benefits (termed here the *ridership proxy method*). In this case, pronouncements on the vertical equity of the scheme are made by comparing the distribution of passengers to that of the underlying population. Only if the proportion of passengers from lower income categories exceeds its share of the population, is the scheme described as progressive as the user benefits are disproportionately skewed towards these groups (and vice versa).

Assessment of direct impacts is consistent with traditional economic appraisal methods focusing on the benefits and costs of transport investments directly attributable to the investment. This approach has been criticised for failing to account for environmental impacts and other externalities, or social justice impacts such as accessibility, liveability, and affordability (Cervero, 2011; Martens, 2017). For example, the practice of valuing journey time savings with reference to the wage rate of the user would tend to weight the time-savings of mobile-wealthy citizens more than those of the poor, while ignoring the social cost of suppressed demand (where some journeys may not be made at all because there is no viable transport service), in both instances hampering the correct identification of equity problems.

In response to such criticisms impact evaluation has evolved to adopt a wider set of impacts in at least two ways. The first approach considers additional non-user, societal, and system impacts (termed *indirect impacts* in Table 1), but does not attempt to monetise them. Examples include wider traffic impacts, environmental or health impacts, and changes to property values, employment, and access to opportunities. A tool that has been particularly useful in this regard is accessibility measurement. The development of accessibility measurement techniques has seen much research activity in the past few decades (for recent reviews, see for instance El-Geneidy and Levinson, 2006; Geurs and Van Wee, 2004), consistent with an acknowledgement that the key benefit of transport is not simply mobility but the accessibility to opportunities it bestows (Handy and Niemeier, 1997; Zengras, 2011). The most common approaches simply measure or map distances to transport routes or interchanges (e.g.

Jaramillo et al., 2012; Teunissen et al., 2015), or make the link through to the number of opportunities (jobs, medical services, food stores) reachable via the transport system (e.g. Levinson, 1998; Lucas et al., 2008; Venter, 2016). Accessibility measures have proven useful for equity analysis, for instance when comparing the distribution of access benefits of new transport systems across income or spatial groups (e.g. Bocarejo and Oviedo, 2012; Fan, Guthrie and Levinson, 2010; Manaugh and El-Geneidy, 2012). Accessibility measurement has also been central to the understanding of social exclusion and the design of plans and interventions to combat transport-based exclusion (Curl, Nelson, and Anable, 2011; Farrington, 2007; Lucas, 2012).

However social exclusion is not solely the result of a lack of transport to reach a destination, but is also a process – a lack of access to decision-making around the very transportation that is meant to serve a community (Casas and Delmelle, 2014). Process evaluation would consider the inclusiveness with which problem identification, plan preparation, and project implementation is undertaken, and pays attention to issues such as information, communication, and public participation. Studies of the processes of BRT implementation are so scarce that the paper does not consider this aspect in detail.

The second major approach to widening the scope of impact evaluation is to include only wider impacts that can be monetized and included in the conventional benefit-cost analysis framework (termed *integrative appraisal* in Table 1). External costs (e.g. environmental and climate change costs) and benefits (e.g. agglomeration and accessibility gains) are increasingly included in *ex ante* and *ex post* economic appraisals of transport projects (e.g. Geurs, van Wee and Rietveld, 2006; Hidalgo, Pereira, Estupiñán, and Jiménez, 2013; Weisbrod, Mulley and Hensher, 2015). Applied to equity analysis, benefit-cost ratios can be calculated not only at the aggregate or project level, but also by socio-economic group in order to reflect the distribution of net benefits (or disbenefits) across the population (Commonwealth of Australia, 2006; Jenkins and Harberger, 1997). Provided costs and benefits can be

allocated accurately to specific segments, distributional cost-benefit studies provide useful insights into the vertical equity impacts of transport projects such as Bus Rapid Transit.

3. THE EQUITY IMPACTS OF BRT: RECENT EVIDENCE

There has been a steady rise in the number of studies examining the social impacts of operational Bus Rapid Transit systems in developing countries. The number of BRT studies addressing some aspect of equity – we identified 68 publications in the academic and grey literatures, most published within the last 10 years – is sufficient to suggest it is time for a closer look at the collective evidence that is emerging. The aim of this section is to review this evidence with a view to identifying emerging trends and conclusions that might inform the formation of sustainable transport policy in the Global South.

The relevant literature was screened based on geographic scope (including only BRT systems from low and middle-income countries in Latin America, Africa and developing Asia), and type of evidence (including only empirical evidence from *ex post* analyses of operational systems). Many studies did not specifically aim to examine equity, but provided useful information on distributional impacts nonetheless. In almost all cases the groups of interest were defined along socio-economic or income lines rather than in relation to need and ability (e.g. by disability status).

The discussion follows the analytical framework presented in Table 1. We first trace the distribution of the direct impacts of BRT systems, including travel time, travel cost, and accident cost reductions to passengers. Most quantitative data are available on these impacts, in line with the fact that speed and efficiency gains are almost always among the primary objectives of BRT deployment. Then follows a discussion of indirect social impacts accruing to users and non-users, including accessibility, property, health, and employment impacts, followed by the evidence on distributional cost-benefit analysis of BRT projects.

3.1 Travel time impacts

There is substantial evidence that BRT systems can deliver significant savings in average passenger travel times. Travel time savings of up to 52 minutes per day and 59 minutes per peak period trip have been reported in Istanbul's Metrobüs (Alpkokin and Ergun, 2012) and in Jakarta (Ernst, 2005) respectively. BRT buses typically achieve gains in average operating speeds in the order of 10 km/h over normal city buses (Carrigan, King, Velásquez, Raifman, and Duduta, 2014) due to a combination of exclusive infrastructure, advanced operational strategies, and speed-enhancing technology (Deng and Nelson, 2013; Hidalgo and Gutiérrez, 2013).

From an equity perspective, the question is how travel time savings are distributed across users. Although passenger travel times are rarely disaggregated by socio-economic group, there is evidence of a progressive impact in some systems. Hidalgo and Yepes (2005) assessed travel time by income segment for Bogotá's TransMilenio Phase 1, and found higher travel time savings for poor people (18 minutes per trip) than for middle income passengers (10 minutes). Progressive travel time impacts might also accrue to low-income pedestrians and cyclists using sidewalks and bikeways upgraded as part of the BRT project. For instance, Tiwari and Jain (2012) showed that both cyclists and bus users save in the order of 33% of their travel time on the Delhi BRT. As most non-motorised transport (NMT) users are from low-income households, the benefit is likely to be progressive.

However this result may be highly variable across systems depending on the scale and location of the BRT network vis-à-vis the residential location of poor communities. Hook and Howe (2005) argue that the deployment of BRT systems with closed trunk and feeder lines may raise travel times if they replace formerly direct bus services and require passengers to make lengthy transfers. There is some empirical evidence to support this: Lleras (2003) found that travel time savings in Bogotá came primarily from drops in in-vehicle travel time, while TransMilenio passengers who require one or more transfers actually experienced a two minute

per trip *rise* in travel time due to increased waiting and transfer times. In many cases, transferring passengers are more likely to come from poor communities, which tend to be located in peripheral locations farther away from trunk BRT lines (Scholl, Bouillon, Oviedo, Corsetto, and Jansson, 2016).

The progressiveness of BRT in terms of travel time may be enhanced by changing speed differentials between bus and car modes. In many systems speeds of private vehicles using the BRT corridor improve due to the removal of buses from mixed traffic lanes and geometric upgrades (Cervero, 2013). However average bus speeds tend to increase far more (Cervero and Kang, 2011), benefiting lower income users who are more likely to be bus than car users. Should car lanes be converted into BRT lanes the equity impact may be even larger. For example, in the case of the controversial BRT corridor in Delhi, Hidalgo and Pai (2009) reported a 14% rise in car travel times, but this was more than off-set by a 35% reduction in travel time for bus users. In fact the redistribution of road space from higher income to lower income citizens is explicitly advocated as a pro-poor intervention (Vasconcellos, 2001).

Taken as a whole, the evidence suggests that BRT might deliver travel time savings to low income communities, but the extent to which this is skewed in their favour depends on a range of location-specific spatial, demand, and infrastructure factors.

3.2 Travel cost impacts

Affordability is a key constraint to mobility among the urban poor, many of whom spend 20 to 30% of their household incomes on travel (Carruthers, Dick, and Saurkar, 2005; Diaz Olvera, Plat, and Pochet, 2008). Although reducing monetary travel costs is not always a stated objective of BRT implementation, it is sometimes argued that BRT systems could bring public transport operating costs down by improving efficiencies, and thus offer more affordable fares to users (Hook and Howe, 2005).

There is scant evidence that BRT systems consistently save users money. In Jakarta, for instance, about half of users said their travel cost was slightly lower when using Transjakarta (Hook and Howe, 2005). In Johannesburg, about two-thirds of Rea Vaya users reported saving about 21% in their daily travel costs, but the remaining one-third reported an increase in costs (Vaz and Venter, 2012).

The reason is that most BRT systems are not priced lower than other modes, especially when they offer a substantially improved service quality. Higher single trip fares (compared to traditional bus fares) have been reported in Bogotá's TransMilenio (Phase 1) (Gilbert, 2008), Curitiba and Sao Paulo (Carrigan et al., 2014), while the average fare level of around US\$0.80 reported by EMBARQ for other BRT cities (Carrigan et al., 2014) is very similar to that in non-BRT cities (estimated from data in Carruthers, Dick, and Saurkar (2005)).

Although *average* fares are typically not lower on BRT, some systems consciously adopt fare strategies to benefit poor users. Flat fares and fare integration are the most important of these. Flat fares allow higher-income travellers with shorter trip distances to cross-subsidise poorer long-distance commuters (e.g. in Curitiba and Bogotá), while free or reduced-fare feeder trips extend the benefits to passengers making long multi-trip journeys (typically from poor, peripheral locations). There is some evidence that such policies promote equity. Hidalgo and Yepes (2005) report total daily savings of 8%-12% of the daily income of low income TransMilenio passengers who would have paid two fares on the traditional system. Lima's integrated and flat fare pricing structure promotes BRT usage among the poor making longer trips by reducing prices below those of traditional modes (Scholl et al., 2016).

Where BRT deployment results in the formalisation of previously informal fare practices (typically on paratransit systems), both positive and negative impacts can occur. On Lagos' BRT 'Lite', the standardisation of fares that used to vary by the hour brought cost savings to many passengers (ITP, 2009). On the other hand, Kash and Hidalgo (2012) report that

TransMilenio's automated fare system removed the possibility for poor passengers to negotiate fare discounts, as was common practice with Bogotá's informal bus operator.

It is concluded that the combination of a higher service quality and limited political appetite for subsidy means that BRT fares are in practice not necessarily lower than on other public transport options. This could have negative impacts on equity, as it might price potential poor users off the system. However careful design of fare policies and effective integration with feeder modes can mitigate some of these negative effects.

3.3 Road user safety impacts

Recent studies have shown that BRT implementation can substantially improve traffic safety by reducing the frequency of traffic incidents, injuries and fatalities (Bocarejo, Velasquez, Díaz, and Tafur, 2012; Duduta, Adriazola, Hidalgo, Lindau, and Jaffe, 2012; Hidalgo et al., 2013). EMBARQ estimates that, on average, BRTs in Latin America and India contributed to a 52% drop in fatalities and a 39% drop in injuries, controlling for citywide accident trends (Carrigan et al., 2014). Improved safety results from BRT-related interventions such as better street and crossing design, dedicated pedestrian and bicycle infrastructure (Duduta, Adriazola, Hidalgo, Lindau, and Jaffe, 2014; Welle et al., 2015), and improved driver behaviour due to the elimination of on-street competition for passengers (Bocarejo et al., 2012).

No specific equity analyses have been performed of these impacts, but road safety improvements would benefit lower income users to the extent that they are represented among bus passengers. However these benefits might be offset by a decrease in safety for pedestrians, who are even more likely to be from low-income groups. For instance, Bocarejo et al. (2012) find that along two of TransMilenio's corridors, despite an overall decrease in traffic accidents, accident rates have risen around busy stations and along roads where private vehicle speeds increased in response to traffic engineering enhancements. These are the types of locations where pedestrians are more likely to be affected. Tiwari and Jain (2012)

raised concerns around crash risks for pedestrians along the Delhi BRT corridor, while an analysis by Duduta et al. (2012) of accidents in nine BRT systems in Latin America and India showed that 54% of fatalities on and around busways were pedestrians, leading the authors to conclude that “road safety on bus systems is primarily an issue of pedestrian safety” (Duduta et al., 2012, p. 10).

The tentative conclusion is that although good BRT design seems to enhance vertical equity in terms of overall improvements in road user safety, the impact may be limited unless the safety of non-users – pedestrians, cyclists and bus users on the walking part of their trip – is addressed. There remains a need for more research on the links between specific BRT-related design elements and road safety for various user groups (Vecino-Ortiz and Hyder, 2015).

3.4 Distribution of ridership as proxy for user benefits

A number of studies have compared the percentage of BRT users per income group (usually compiled from user surveys) with that of the population at large, in an effort to judge whether benefits are skewed towards lower income groups. Table 2 summarises the data available for six cities. The data show that the largest proportion of users in all of these cities is from the middle income categories, typically corresponding to income quintiles 2 to 4. Compared to city-wide distributions, medium income people tend to be overrepresented on BRT systems, suggesting that BRT does not serve the lowest income users particularly well.

These findings echo those of earlier studies. In 2008 Gilbert undertook a wide-ranging assessment of the extent to which TransMilenio, as a governance intervention, has brought benefits to the poor of Bogotá. He concluded that “[w]hat is less certain is how much Transmilenio has so far helped the poor” (Gilbert, 2008, p.458). He attributes this to two factors: incomplete route coverage (Phase 1 missed most of the poor areas of the city) and fare levels being higher than on the traditional system. Hidalgo and Yepes (2005) came to a

similar conclusion noting that while 37% of Phase 1 passengers came from the two poorest strata of the city, these strata represented 44% of all citizens.

The same arguments are likely true for the other cities in Table 2. In Mexico City, Metrobús Line 3 serves primarily middle-income areas (Carrigan et al., 2014). In Ahmedabad, the Janmarg BRT system attracts primarily middle-income groups, despite the route's location within walking distance to many low-income dwellings and slums, and despite pro-poor aspirations expressed in the project proposal (Mahadevia et al., 2012). In Johannesburg, the first BRT line serves an income-diverse population, but a survey of households located within the BRT corridor indicates that poor users are underrepresented on BRT, even *when controlling for access* (Table 2) (Vaz and Venter, 2012). Pricing is the most likely explanation: BRT fares are set higher than those on competing services, at a level where the lowest income users are not willing to pay for the faster and more reliable service it offers. It is telling that Istanbul's Metrobüs, the only system in Table 2 where ridership is skewed towards low-income groups, has managed to decrease the average fare (including transfers) for BRT users by more than 50 percent from previous levels (Yazici et al., 2013).

3.5 Accessibility changes

There is now substantial evidence that BRT has the potential to significantly impact on residents' ability to access opportunities across the urban space by enhancing connectivity and lowering travel times (Cervero, 2013). However, systems vary considerably in terms of the accessibility gains enjoyed by individual groups, and the resultant impact on social exclusion and poverty.

The equity impact of accessibility gains depends firstly on the proximity of BRT routes to the residential location of low-income communities. Most trunk routes are initially deployed along high volume corridors in and near city centres, where they tend to serve older, more well-off neighbourhoods better. For example, the first phases of the *Masivo Integrado de Occidente*

(MIO) BRT system of Santiago de Cali (Colombia) covered only 9% of city districts, located mostly in the central parts of the city (Jaramillo et al., 2012), and skewing benefits in favour of the middle and upper-middle strata (Delmelle and Casas, 2012).

More mature systems use extended trunks and/or denser feeder networks to enhance the accessibility of poor neighbourhoods. The Cali case is instructive: the addition of new trunk and feeder routes since 2012 has meant that 92% of the extremely poor can now reach a MIO route on foot within 15 minutes, although access is still poor in steep and hilly areas lacking sidewalks and stairs (Scholl et al., 2016). In Lima, trunk lines are concentrated in upper income areas, but feeders serve many middle- to lower-income areas (Scholl et al., 2016). In Bogotá, while earlier studies expressed concern about the uneven coverage achieved by the Phase 1 network (Gilbert, 2008), Teunissen et al. (2015) finds that with the addition of later phases access is evenly distributed across socio-economic strata.

Accessibility gains depend not only on access to the BRT, but also to destinations *via* the BRT. Several studies have measured significant gains in accessibility of poor workers to jobs located in central employment areas, especially where BRT systems significantly reduce travel times compared to previously congested or informal services. Examples include Bogotá (Bocarejo and Oviedo, 2012; Bocarejo, Portilla and Meléndez, 2016; Hidalgo and Yepes, 2005), Ahmedabad (Zuidgeest, Nupur and Talat, 2012), and Delhi (Tiwari and Jain, 2012). In Delhi, Tiwari and Jain (2012) also demonstrated that accessibility to other opportunities such as schools and shops increased significantly, both for bus users and for bicyclists using the corridor.

What is less clear is how much radial BRT systems contribute to enhancing accessibility in more decentralised, low-density cities, such as African cities where many job opportunities are informal and widely dispersed across space (Vaz and Venter, 2012). In such cases, even if spatial accessibility improves through effective feeder strategies, poor passengers may experience an overall reduction in accessibility due to fare increases, especially when

transfers between different modes are required (Bocarejo et al., 2014; Venter, 2016). Issues of accessibility impacts in the context of integrated systems need much further exploration.

3.6 Property and housing impacts

The majority of BRT systems are too young for strong impacts on land use or property prices to be observed. A few hedonic and time-series price studies in Bogotá, Seoul and Beijing have assessed the effect of BRT trunk line development on property prices. The bulk of studies show positive trends in land prices in areas that are within walking distance of BRT stations, equating to price premiums of up to 10% (Cervero and Kang, 2011; Deng and Nelson, 2010; Perdomo Calvo, Mendoza, Baquero-Ruiz, and Mendieta-Lopez, 2007; Rodriguez and Mojica, 2008; Rodriguez and Targa, 2004). A few studies failed to detect positive price impacts (Muñoz-Raskin, 2010; Zhang and Wang, 2013).

The key equity concern here is the potentially detrimental effect of gentrification on housing affordability for low-income households. Once again, the available evidence is mixed. Muñoz-Raskin (2010) studied differential impacts on residential property prices by economic stratum in Bogotá. He found that the low-income market did not pay more for housing with good access to TransMilenio stations, but that properties owned by middle-income households captured price premiums related to BRT access. However Bocarejo, Portilla and Pérez (2013) found that TransMilenio contributed to significant densification in some areas. As densification is partly a response to rising property values, they cannot rule out the possibility that access to affordable land is reduced. Recognising this, the city of Bogotá has launched a land banking initiative (Metrovivienda), in terms of which the municipality buys land located close to future TransMilenio trunk routes before their values start rising, and then regulates the development and reselling of these properties to be affordable to the poor (Cervero, 2005). Price reductions of 25% below market rates have been reported (Hook and Howe, 2005). Yet Bocarejo et al. (2013) argue that a large segment of the population is still not able to afford housing.

Similar concerns have been raised in Curitiba, where the RIT has been in operation long enough – and where land use policies have been supportive enough – to observe long-term impacts. Over five decades Curitiba's well-documented urban development concept has resulted in densification around radial trunk routes (Duarte, Firmino and Prestes, 2011) and strong BRT ridership. Yet examining origin-destination patterns along the system's trunk lines, Duarte and Ultramari (2011) conclude that as many as 80% of the passengers do not live along the main BRT corridors, but in peripheral towns beyond the end terminals from where they commute long distances to jobs in the city centre. They blame this on the property market: land along the BRT corridors is “among the most expensive in town” (Duarte and Ultramari, 2011, p.11) due to restrictive zoning policies and excessive land speculation that limits the supply of housing along the corridors. This is somewhat discouraging, as it implies that the very success of BRT helps to price low-income households out of exactly the residential locations that are most beneficial to them in terms of accessibility.

3.7 Impacts on employment

The employment prospects of low-income workers may be directly affected by BRT deployment. Some new jobs are created in construction, operations and maintenance, but these are relatively few. For example, for TransMilenio Phases 1 and 2, Hidalgo et al. (2013) estimate a net figure of between 1900 and 2900 permanent jobs created in operations, plus 1400 to 1800 jobs per month in construction. More significant impacts might be associated with the restructuring or replacement of traditional transport services that often accompanies BRT deployment. Paratransit services are significant sources of employment of low-skilled workers (Cervero and Golub, 2007); their restructuring or replacement might reduce employment in the sector. In Cali, BRT implementation involved a reduction in route-kilometers from 10,235 to 909km; and in vehicles from 4289 vehicles to 937 (Jaramillo et al., 2012). Not all of these drivers were necessarily absorbed into BRT operations. However, when specific steps are taken to mitigate job losses, the net employment impacts of BRT on low-wage

workers might be neutral or slightly positive. This was the case in Bogotá (Hidalgo et al., 2013), as well as in Johannesburg's first phase BRT where of the 580 informal minibus-taxi drivers removed from the route, most were retrained and employed as bus drivers or station staff (McCaul, 2012). Formalised workers were also better off in terms of earnings, benefits, and working conditions than before (McCaul, 2012).

3.8 Health impacts

BRT deployment could improve community health in two ways: by improving air quality, and by promoting physical activity. Improvements in air quality may result from reducing private vehicle use, from improving traffic flow, and from replacing old or poorly maintained bus or paratransit vehicles with modern low-emission buses. A number of studies have found air quality benefits to be significant, for example in Mexico City (Wöhrnschimmel et al., 2008), Bogotá, Guangzhou and Jakarta (Nugroho, Fujiwara, and Zhang, 2011; Vincent, Delmont, and Hughes, 2012). Hidalgo et al. (2013) valued the health benefits, in terms of reduced premature deaths and lost work days, from TransMilenio's first two phases at about \$114 million over a twenty-year period.

Yet these health benefits are not necessarily distributed equitably across socio-economic groups. Firstly, local air quality improvements occur around BRT corridors, which, as previously shown, are often concentrated around middle-income or wealthy areas of the city. Secondly, such improvements might be partially offset by a deterioration in air quality in other areas – typically lower income neighbourhoods – where the BRT is not operating. For example, over the first five years of TransMilenio operation, air pollution levels rose in unserved parts of Bogotá (Echeverry et al., 2005), offsetting the gains around BRT corridors (Hidalgo and Yepes, 2005). Echeverry et al. (2005) blamed this partly on the displacement of old buses from the BRT corridors. This in effect reduced equity as it redistributed air pollution costs towards poorer parts of the city. Such situations are likely to improve over time as BRT

networks grow, but it is important to note that during the first few years of BRT operation some groups might be especially vulnerable in terms of equity impacts.

The health benefits of BRT in terms of increased physical activity result primarily from switching passenger demand from more sedentary modes such as cars. In developing countries the percentage of passengers attracted from private cars is typically below 15 percent (e.g. 8% in Mexico City; 12% in Beijing; 11% in Johannesburg (Deng and Nelson, 2010; McCaul, 2012; Wirasinghe et al., 2013)). Lower income passengers most likely come from other public transport and non-motorised modes. Physical activity benefits are therefore likely to be larger among higher and medium income users than among low-income groups.

3.9 Distributional cost-benefit analysis

While cost-benefit analyses are often conducted as *ex ante* exercises during the planning of and motivation for BRT projects, a small number of *ex post* cost-benefit studies have been published lately for implemented BRT systems (Echeverry et al., 2005; Hidalgo et al., 2013; Instituto Nacional de Ecología (INE), 2008; Seftel and Peterson, 2014). A comprehensive review of these studies is outside the scope of the paper, but it seems clear that despite significant variation in the extent of benefits and costs considered, most studies have found BRT implementation to be beneficial at the system level. Overall benefit-cost ratios of between 1.2 and 2.8 seem to be typical (Carrigan et al., 2014). Two studies reported unfavourable benefit-cost ratios in Bogotá (Echeverry et al., 2005) and Johannesburg (Seftel and Peterson, 2014), in both cases due to the high costs associated with transitioning from an informal, chaotic public transport system towards a formalised BRT-based system that might overshadow system benefits for at least the first few years of operation.

A few studies have looked at the distribution of costs and benefits across user groups, rather than for society as a whole. Carrigan et al. (2014) recently reported results for four BRT systems (in Bogotá, Mexico City, Istanbul and Johannesburg). The method rests on allocating

both user and non-user benefits across income strata according to the proportion of the population the benefits accrue to; and allocating costs (including planning, infrastructure and maintenance costs) based on the proportional contribution of each income group to tax revenues. The value of travel time savings is estimated using a single (average) value of travel time across all income groups to avoid biasing travel time benefits towards higher-income groups.

Figure 1 shows the results for each of the four cities. In each case BRT investment is progressive: benefits exceed costs by a larger proportion for lower income than for higher income groups. This is partly driven by the concentration of benefits (especially time savings) among BRT users in the lower and medium income groups. The majority of costs are paid with tax-funded public funds, which are disproportionately contributed by the higher income strata. In fact, in all cases except Istanbul, the highest income group experiences a net loss (costs exceed benefits), indicating that BRT serves an income distributive function.

In all four case-study areas residents in the lowest quintile receive positive net benefits, but both absolute benefits and benefit-cost ratios tend to be highest in medium income strata containing most passengers. This observation leads Carrigan et al. (2014) to conclude that “while the BRT projects tend to be progressive and beneficial to lower-income strata, the lowest-income residents are not benefiting the most from the four projects.” The authors recommend that “[e]nsuring that the poorest residents are well represented among BRT users is key to their benefiting more from BRT projects. This may require special attention during project planning to make BRTs accessible to the poorest residents; it also requires careful structuring of user fares compared to existing transport modes and may necessitate targeted fare subsidies” (Carrigan et al., 2014, p. 16).

4. DISCUSSION

Worldwide, Bus Rapid Transit (BRT) systems are being planned and developed apace. BRT is particularly suited to deployment in developing countries due to its lower construction costs, shorter construction lead-times, and lower technological hurdles when compared to other mass transport systems such as light or rapid rail. This positions BRT systems as key interventions able to facilitate social justice, poverty reduction, and vertical equity among urban populations. It is therefore unsurprising that there is a growing interest, both among scholars and funding agencies, in documenting and understanding the equity impacts of BRT (and other urban transport projects). This paper reviews and reflects on the main findings of this literature to date, with a view to identifying any course corrections needed to steer towards more socially sustainable transport interventions.

4.1 Methodological issues

It is clear that Bus Rapid Transit systems have potentially significant equity impacts. However the identification and measurement of these impacts is hampered by the lack of a clear and consistent framework for equity analysis that can be applied and compared across different locales. Of particular value would be identification of a common set of equity or distributional indicators, similar to those that have been adopted for Clean Development Mechanism funding and reporting purposes.

Two established techniques that we consider to hold most promise in this regard are accessibility measurement, and distributional cost-benefit approaches. The literature on accessibility measurement is growing fast, but a greater emphasis is needed on its use for disaggregating accessibility, as the central benefit of transportation projects, across different user groups. New approaches such as open and crowdsourced data and open software might be helpful in this regard (e.g. Owen and Levinson, 2014; Quirós and Mehndiratta, 2015). More work – perhaps qualitative in nature – is also needed to link accessibility more directly to

poverty outcomes. For instance, can it be demonstrated that BRT-enhanced accessibility leads to better employment prospects, higher civic participation, or higher quality of life for an individual or household? Once such linkages are better understood, BRT systems can be better targeted to achieve the poverty outcomes sought by governments and funders.

Distributional cost-benefit approaches have the advantage of being firmly rooted in conventional economic evaluation practices, and are thus more likely to be accepted within current decision making processes. Granted the limitations of cost-benefit analyses in general, these methods can, with relatively straight-forward extensions, deliver useful insights into the distributional impacts of public transport investments and help to balance the efficiency objective of conventional project assessment with more socially responsive perspectives. We would like to see more empirical analyses of existing systems. More work is also needed on the valuation of benefits of particular relevance to low-income transit and NMT users, including option value, convenience, and secure transit environments.

Better data are clearly needed to support more rigorous assessment of equity impacts in transport implementation. When BRT systems are evaluated there is a need for greater disaggregation of user groups, to allow comparison across socio-economic strata (and other groups of interest such as women and children). For instance, health and traffic safety benefits are typically reported in the aggregate rather than by group.

4.2 Vertical equity impacts of BRT systems

The weight of the evidence indicates that BRT systems, as currently deployed, do offer significant real benefits to lower-income communities in many developing cities. Demonstrated benefits include increased access to opportunities, travel time and cost savings, and health and safety benefits. However, the benefits do not seem to go as deeply as they might, and are in many cases concentrated among the higher strata of the poor and the middle-income, bypassing the poorest who arguably suffer most from exclusion-based poverty. BRT systems

are not, in general, as progressive in their impacts as they could be. Two dominant reasons emerge for this: lack of coverage, and pricing.

Most BRT systems in the Global South deploy their first trunk services along central parts of cities, skirting more peripheral areas where the poor tend to live. While feeder services might extend user benefits to peripheral areas, these benefits are often diluted by low feeder speeds and lengthy transfers. Systems that have extended the coverage of trunk services more directly into peripheral, low-income areas, despite the physical challenges this may entail – such as TransMilenio (Bogotá) and MIO (Cali) – have demonstrated more equitable coverage benefits. An alternative is the use of full-flex approaches, in terms of which BRT buses leave trunk corridors to penetrate more deeply into neighbourhoods without requiring passengers to transfer.

This raises the issue of timing: the vertical equity of many BRT projects seems to improve over time. Not only do many benefits result from network effects, which grow significantly as the network expands, but many negative impacts, particularly in the early stages of deployment, might be due to what Echeverry et al. (2005) call ‘spillover effects’. Where BRT co-exists with a weakly regulated, poorly operated informal system, substantial negative impacts may be imposed on the rest of the city, much of which may fall on peripherally located poorer communities. Gradual expansion of the network may in time reduce these effects. The corollary is that failure to complete the transformational expansion of the public transport network, either due to increasingly difficult and costly construction (e.g. in peripheral slums without proper roads), or to growing resistance from incumbent operators who lose their businesses, may leave vulnerable communities worse off than they were before.

We conclude that the approach, pace, and comprehensiveness with which authorities deal with incumbent operators and legacy (informal) systems can have major equity consequences for both low-income passengers and operators. Paratransit reform is an evolving project; no consensus has been reached about the most appropriate paths to be followed. But regardless

of the path, it is important that authorities carefully consider equity impacts and mitigation of negative spillover effects via effective regulation and transitional strategies.

A second factor that often skews user benefits away from low-income users is pricing: BRT seems to be priced higher, on average, than competing, lower-quality services (often informal or unregulated). There is evidence that, in many cities, affordability constraints put BRT out of reach of the poorest users. This could have disastrous consequences for their mobility if alternative (informal) services are removed in terms of larger public transport regulation programmes.

4.3 Implications for sustainable transport policy

BRT as a concept possesses characteristics that potentially enable it to serve traditionally under-served populations better than other mass transit alternatives. For example, by focusing on speed improvement, BRT can improve access for the spatially excluded, but do so at a cost (to both governments and users) that is lower than comparable rail-based solutions. As a surface mode it can be better integrated with urban amenity and non-motorised transport (NMT) improvements, which particularly benefit the poor. This makes BRT a potentially powerful ingredient of socially sustainable transport policy in the Global South.

However it seems clear that these equity benefits do not follow automatically, but occur only where a dedicated, sustained effort is made by policy makers and system implementers to achieve pro-poor objectives. In this BRT is of course no different than any other transport intervention, but, we argue, BRT's particular strengths might make these objectives easier to achieve.

The collective evidence further suggests that the single most important advance needed to enhance the effectiveness of BRT as a pro-poor intervention is to pay better attention to its integration within the urban fabric. Better integration is needed in terms of land use and housing patterns, road safety and street design, as well as other transport services.

In terms of spatial issues, apart from the points raised above regarding the improved alignment of BRT routes with low-income residential locations, this should be done in the context of overall housing policy in such a way that access to affordable housing is protected. The available evidence raises very real concerns around gentrification and property value increases near BRT trunk routes that might price low-income households out of exactly the residential locations that are most beneficial to them in terms of accessibility. Further evidence is needed on both this phenomenon, and the effectiveness of land banking and other interventions aimed at offsetting the negative effects on the poor.

More flexible integrative approaches are needed towards routing and infrastructure. In many ways a heavily corridor-oriented, 'closed', and radial route strategy – which is typical for BRT systems – does not suit the dispersed travel needs of poorer passengers well. The increasing importance of informal sector activities in many developing cities creates a greater need for irregular or circumferential movements associated with hawking, trading or employment-seeking (Howe and Bryceson, 2000). Further thinking is needed on how the advantages of BRT can be married with flexible, open transport services to serve a variety of travel needs conveniently and affordably. These might include cooperation with existing informal paratransit operators (Ferro and Behrens, 2015) or local bus services.

A critical component of integration with other transport modes is to link better with non-motorised transport networks. Several authors have argued that, given the prevalence of walking or cycling among poor people, it may be more effective to use resources to improve sidewalks and other non-motorised transport infrastructure than subsidising public transport (Howe and Bryceson, 2000; Serebrisky, Gómez-Lobo, Estupiñán, and Muñoz-Raskin, 2009). Similarly, in the case of BRT systems, their accessibility gains could be made much larger by improving their reach by non-motorised transport improvements, which have the additional effect of improving neighbourhood access for everyone (Zuidgeest et al., 2012).

Integrating pricing between BRT and other public transport services is another key to unlocking progressive impacts. Pro-poor fare structures and free transfers help demonstrably, especially if they include other feeder services connecting to the BRT system. It is important that BRT planners are aware of the fact that fare policies have a major influence on the equity impacts of their services.

Two aspects of BRT implementation with potential equity dimensions that we did not consider are political inclusion and urban design. Regarding the first, a few studies have started to examine the extent to which BRT engages and empowers disadvantaged groups in society (Casas & Delmelle, 2014; Paget-Seekins, 2016; Sagarias, 2016; Rizzo, 2014; Schalekamp & McLachlan, 2016). Paget-Seekins (2015) argues that, by visibly prioritising road space for public and non-motorised transport, BRT systems put the mobility needs of public transport users on the public agenda, contributing to greater political inclusion. However others have questioned the quality of actual engagement that accompanies many BRT implementation processes (Kash & Hidalgo, 2014; Mahadevia et al., 2012). The area of process evaluation is one on which much further research and reflection is needed, before conclusions can be drawn on the responsiveness of BRT to community needs.

Lastly, BRT systems might pull together and connect parts of the city in ways which other (informal) systems don't, especially at the level of urban identity, level of service, and spatial coherence. Urban design, precinct upgrading and the provision of urban amenities associated with BRT projects may benefit poor people through a reclamation of urban space (Wright and Montezuma, 2004). In practice, however, there is some evidence that cities do not always pay sufficient attention to these ancillary infrastructures, especially if system implementers are under pressure to maintain road capacities for mixed traffic in narrow rights of way (Mahadevia et al., 2012). As urban design and road space management may particularly affect poorer residents and traders, this is clearly an area for further research. We also still need to develop conceptual tools and methods to assess the long-term impacts of such interventions on rates

of motorisation and the spatial development path of cities, and whether or not they become more inclusive, accessible, and equitable.

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Table 1: Conceptual outline for assessing vertical equity of BRT systems

Type of impact considered	Method of allocation across groups	
<u>Direct impacts</u> (benefits and costs accruing to users ¹) <ul style="list-style-type: none"> • Travel time changes • Travel cost changes • Road safety impacts • Health impacts (active modes) 	<u>Direct allocation:</u> Total or average impact measured per socio-economic user group	<u>Allocation by ridership proxy:</u> Distribution of ridership across socio-economic user group
<u>Indirect impacts</u> (benefits and costs accruing to non-users and society at large) <ul style="list-style-type: none"> • Congestion impacts • Accessibility (exclusion) changes • Property values and land use changes • Environmental/health/climate impacts • Employment impacts • Political inclusion impacts 	<u>Direct allocation:</u> Total or average impact measured per socio-economic group	
<u>Integrative appraisal</u> (benefits and costs to users and non-users, considered in common monetised framework)	<u>Direct allocation:</u> Benefits and costs allocated per socio-economic group (users and non-users)	

Notes: 1. Users might include both public transport and non-motorised transport users using BRT-related infrastructure and services.

Table 2: Income distribution of BRT users and comparison groups for selected BRT systems in Global South

(Sources: based on Carrigan et al., 2014; Vaz and Venter, 2012; Mahadevia et al., 2012; Scholl, 2016)

BRT system	Scope		Income group*				
			1 (lowest)	2	3	4	5 (highest)
TransMilenio, Bogotá	Phases 1 & 2	Percentage of users	6	40	39	13	3
	City	Percentage of population	9	42	35	9	4
El Metropolitano, Lima	Line	Percentage of users	26		34	40	
Metrobús, Mexico City	Line 3	Percentage of users	22	33	32	11	1
Janmarg, Ahmedabad	System	Percentage of users	14		21	50	15
Rea Vaya, Johannesburg	Phase 1A	Percentage of users	4	4	13	59	20
	City	Percentage of population	20	4	11	22	43
	BRT service area	Percentage of population	10	9	14	41	26
Metrobüs, Istanbul	Phases 1-4	Percentage of users	14	45	22	10	9
	City	Percentage of population	4	20	19	16	41

Notes: *Income groups refer to either income quintiles or locally defined income strata.

Bold indicates BRT users are overrepresented as compared to share of the population in income group

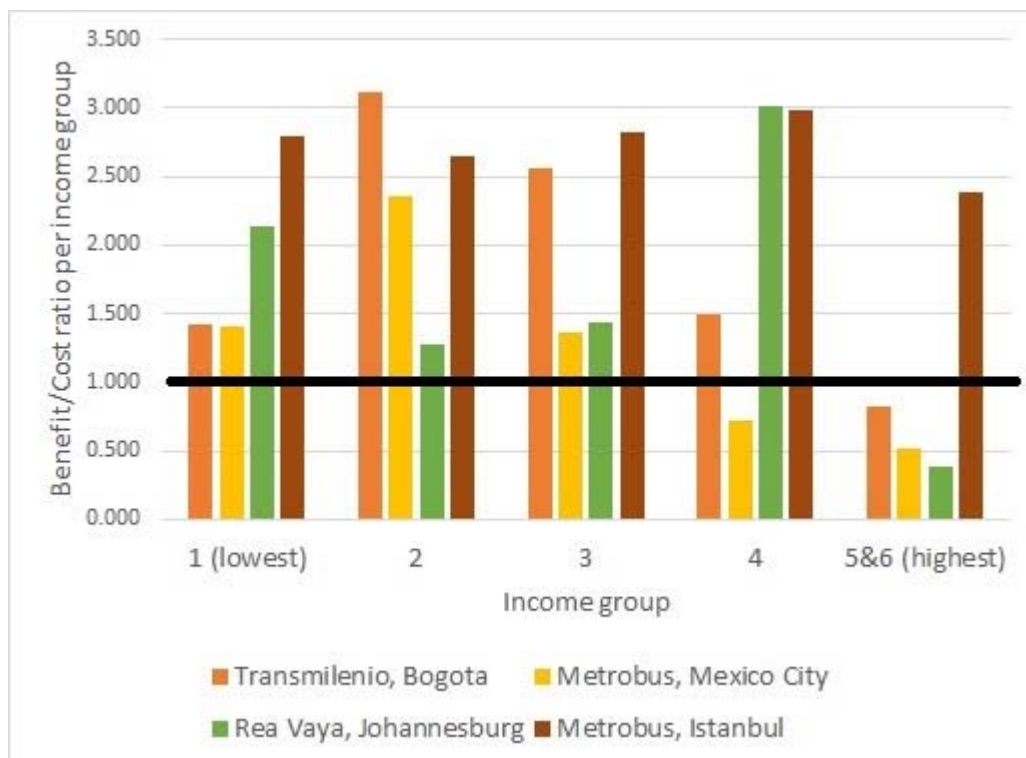


Figure 1: Distributional analysis of costs and benefits in four BRT systems (see Table 2 for extent of BRT systems considered) (based on Carrigan et al., 2014)